Original Article

Evaluation and Comparison of Mechanical Properties of Omega and Mushroom Loop

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Abstract

Background: The aim of this study was to compare and evaluate the mechanical properties of Mushroom loop and omega loop using two different diameters of stainless-steel wire and Titanium alloy. **Materials and Methods:** The sample consists of 40 orthodontic loops for space closure made by the same operator. Loops were made from straight lengths of two different cross-sections that are 0.017” × 0.025” and 0.019” × 0.025” using two beta-titanium alloy (TMA) (Ormco, Glendora, CA-USA) and stainless steel (Ormco Corp), respectively. The sample is divided into two groups. Group 1 and Group 2 of the sample consist of 20 Mushroom loops and 20 Omega loops each, respectively. The samples were subjected to tensile loading tests with different activations in Universal Testing Machine (JINAN, CHINA, ISO6892, WDW-100 Max load [KN] 100) at MSME Testing station, Industrial Estate, Hyderabad. Data were analyzed using SPSS Version 28. **Results:** Tensile strength with 0.019 × 0.025 stainless steel in Mushroom loop and omega loop has a lower mean tensile strength compared to the 0.017 × 0.025 stainless steel. TMA 0.017 × 0.025 in both the groups has higher tensile strengths with mean of 1578.02 (SD 22.82) and 1623.58 (SD 44.8), respectively. *Post hoc* tuckey test results showed a significant difference between mushroom loops using 0.017 × 0.025 inches and 0.019 × 0.025, Mush room loop (0.017 × 0.025) and omega loop (0.019 × 0.025), Mushroom (0.019 × 0.025) and Omega (0.017 × 0.025), and Omega loop (0.017 × 0.025) versus omega (0.019 × 0.025). **Conclusion:** According to this study, orthodontic space closure must be individually assessed based on the diagnosis, desired tooth movement, and treatment plan.

Keywords: Mechanical properties, Mushroom loop, Omega.

Introduction

Closure of extraction spaces is an integral stage of many orthodontic treatment plans. Space closure can be classified by the amount of anchorage loss (or mesial movement of the posterior segments) into retraction, attraction, and protraction cases based on the treatment plan goals.[1,2] Retraction cases are those cases, in which maintenance of the anchorage is critical, little, or no mesial movement which is allowable. Attraction cases utilize symmetric space closure where the space is equally closed by movement of the anterior teeth distally and mesial movement of the posterior teeth. Protraction is where the significant proportion of the space is closed through mesial movement of the posterior teeth.

In each of these three cases, different mechanical systems are required to attain the treatment goals. Three important variables which are under the control of orthodontist are the moment-to-force ratio, the magnitude of the force and/or moment, and the force constancy. The moment-to-force ratio determines the center of rotation of a tooth or segment of teeth, thus allowing translation, tipping, or root movement.[3,4] Kuhlberg and Burstone (1997) evaluated the effect of off-center positioning of the force system produced by asymmetric T-loop spring made of 0.017 × 0.025 inch TMA wires, the results showed that the moment to force ratios increase with decreasing activation. The study concluded that a centered T-loop produced equal and opposite moments with negligible vertical forces.[5] A standard shaped T-loop can be used for differential anchorage by altering the activations and mesiodistal positions of the spring.[6] Ferreira (1999) conducted a study to determine the load-deflection ratio of double delta closing loops. A sample of 72 Loops was divided into 33 stainless steel, 26 cobalt-chromium, and 13 titanium molybdenum loops. They compared four different cross-sections of wires on a linear displacement

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Table 1: Sample distribution of mushroom and omega loops

Type of Loop	Metal alloy composition	Arch wire cross-sections	No of loops
(Group – 1) Mushroom loops	Stainless steel	0.017×0.025	5
		0.019×0.025	5
	Titanium molybdenum alloy	0.017×0.025	5
		0.019×0.025	5
(Group – 2) Omega Loops	Stainless steel	0.017×0.025	5
		0.019×0.025	5
	Titanium molybdenum alloy	0.017×0.025	5
		0.019×0.025	5
		Total	40

transducer activated at 0.5 mm intervals, from neutral position to 3.0 mm through tensor micrometer. Results showed a significant difference among the three types of alloys, stainless steel of 0.019 × 0.025 inch showed highest spring load which averages to 431 g, followed by the cobalt-chromium of 308 g, and titanium molybdenum of 200 g. Titanium-molybdenum with 0.017 × 0.025 inch springs showed the smallest loads and the best spring rate (b = 84.9 g/mm). Highest average load was 480 g/mm exhibited by 0.019 × 0.025 inch stainless steel and the smallest total average load of 149.4 g/mm was exhibited by the titanium-molybdenum 0.017 × 0.025 inch cross-section. It was concluded that the cross-section, wire material, and activation are very important variables related to the resultant average loads after the activations.[7] One of the most common space closure appliances is the "loops," which are been used in both continuous arch wire mechanics and in segmental arch mechanics. When the "loops" are utilized as a space closing spring in segmented arch orthodontics, the force systems generated by its design can be accurately studied in a laboratory setting.[8,9] It is the objective of this research to experimentally evaluate methods of varying the moments and forces generated to the anterior and posterior segments to obtain differential tooth movement in a laboratory setting and to provide specific clinical assessments permitting the orthodontist to adjust the appliance to meet their treatment goals. The present study will experimentally compare and evaluate the properties of Mushroom and Omega loops. In this present study, we compared and evaluated the properties of two designs of orthodontic space, namely, mushroom loop and omega loop.

Materials and Methods

The sample consists of 40 orthodontic loops for space closure made by the same operator. Loops were made from straight lengths of two different cross-sections that are 0.017" × 0.025" and 0.019" × 0.025" using two different materials beta-titanium alloy (TMA) (Ormco, Glendora, CA-USA) and stainless steel (Ormco Corp), respectively. The dimensions of the loops in the sample groups are 6 mm height and width in diameter. The sample is divided into two groups. Group 1 and Group 2 of the sample consist of 20 Mushroom loops and 20 Omega loops each, respectively. The loops were subdivided based on the metal alloy composition and the dimensions (i.e., 0.017 × 0.025 and 0.019 × 0.025) of the material. The samples were subjected to tensile loading tests with different activations in Universal Testing Machine (JINAN, CHINA, ISO6892, WDW-100 Max load [KN] 100) at MSME Testing station, Industrial Estate, Hyderabad.

Data analysis

All the data are entered in Excel and Exported to SPSS Version 23. Descriptive statistics were reported using mean and Standard deviation. Analytical statistics were used to compare the sub group differences between the various pairs using paired sample t-test and the significance is reported using 0.05 value as the cut off. For comparing between the tensile strength of mushroom loops and omega loops for different size of the material, one-way analysis of variation (ANOVA) was used to compare the difference in the means and significant association between the groups and within the groups. For pair-wise comparison within the group, a *post hoc* tuckey test was done and reported using F-statistic and Significance at 0.05 levels. Comparison graphs were reported as required.

Results

The mean tensile strength of the mushroom loop (Group – 1) using 0.017×0.025 stainless steel is 930.758 (M Pa) (Table 1) with a standard deviation of 3.48 Mpa and the mean tensile strength in omega loop is slightly higher with 977.36 Mpa with standard deviation of 25.97. Tensile strength with 0.019 × 0.025 stainless steel in both the groups has a lower mean tensile strength compared to the 0.017 × 0.025 stainless steel. TMA 0.017 × 0.025 in both the groups has higher tensile strengths with mean of 1578.02 (SD 22.82) and 1623.58 (SD 44.8), respectively, Table 2 and Figure 1.

ANOVA was done to see the difference in the mean tensile strength between the groups. A significant difference was seen among the groups using mush room loop and omega loop. *Post hoc* tuckey HSD beta test was conducted to see the pair-wise difference across the mushroom loop and omega loop using different diameter alloy material. *Post hoc* tuckey test results showed a significant difference between mushroom loops using 0.017 × 0.025 inches and 0.019 × 0.025, Mush room loop (0.017 × 0.025) and omega loop (0.019 × 0.025), Mushroom (0.019 × 0.025) and Omega (0.017 × 0.025), and Omega loop (0.017 × 0.025) versus omega (0.019 × 0.025). Results of the ANOVA and *post hoc* tuckey tests are shown in Tables 3 and 4. Independent paired t-test was conducted to

Table 2: Mean tensile strength of mushroom loop versus omega loop

Alloy material	Size (inches)	Mushroom Loop			Omega Loop		
		Mean	SD	Mean Diff and *P* Value	Mean	SD	Mean Diff and *P* value
Stainless steel	0.017×0.025	930.758	3.48	22.50, *P*=0.00**	977.36	25.97	29.65, *P*=0.04**
	0.019×0.025	908.32	2.30		947.708	16.94	
TMA	0.017×0.025	1578.02	22.82	657, *P*=0.00**	1623.58	44.8	939.5, *P*=0.00**
	0.019×0.025	920.61	8.27		683.63	18.23	

**Represents a significant level of difference

Table 3: ANOVA test results

Groups	Count	Sum	Average	Standard Deviation	F-ratio	*P*-value
Mushroom_0.017 (Group – 1)	10	12543.91	1254.391	341.48	9.25	0.0001**
Mushroom_0.019 (Group – 2)	10	9144.09	914.409	8.69		
Omega_0.017 (Group – 3)	10	13004.72	1300.472	342.33		
Omega_0.019 (Group – 4)	10	8156.69	815.669	140.167		

Table 4: ANOVA – *post hoc* tuckey HSD beta test

Pair-wise comparisons	Tuckeys HSD at 0.05=303.22 HSD at 0.01=376.51	F-value	*P*-value
Mushroom loop (0.017×0.025): Mushroom (0.019×0.025)	339.98	4.27	0.022**
Mushroom (0.017×0.025): Omega (0.017×0.025)	46.08	0.58	0.976
Mushroom (0.017×0.025): omega (0.019×0.025)	438.72	5.51	0.002**
Mushroom (0.019×0.025): Omega (0.017×0.025)	386.06	4.85	0.007**
Mushroom (0.019×0.025): Omega (0.019×0.025)	98.74	1.24	0.81
Omega (0.017×0.025): omega (0.019×0.025)	484.80	6.09	0.0006**

Table 5: Comparison of tensile strength paired sample *t*-test

Sub-group pair	Material type and dimension	Paired differences						
		Mean	SD	SE	95%CI	t	Df	*P*-value
Omega loop versus mushroom loop	0.017×0.025 Stainless steel	46.6	27	12.09	13-80	3.8	4	0.018**
Omega loop versus mushroom loop	0.019×0.025 Stainless steel	39.5	16.81	7.5	18.6-60.38	5.25	4	0.006**
Omega loop versus mushroom loop	0.017×0.025 Titanium Molybdenum Alloy	45	59.5	26.2	28.3-119.4	1.711	4	0.162
Omega loop versus mushroom loop	0.019×0.025 Titanium Molybdenum Alloy	236.98	22.31	9.97	209-264	23.75	4	0.00**

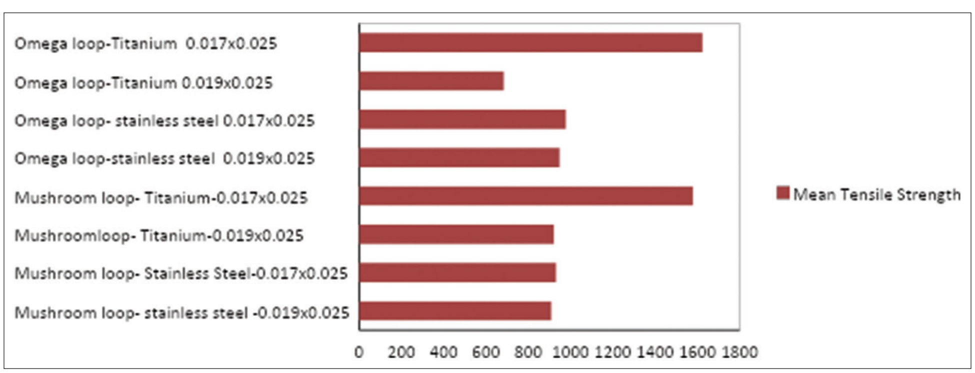

Figure 1: Mean tensile strength across omega loop and mushroom loop

see the statistical difference between the groups in isolation with the type of loop and material (Table 5). Results of the independent paired *t*-test showed a significant difference in the mean tensile strength across the design and the type of alloy.

Discussion

The mean tensile strength of the mushroom loop (Group – 1) using 0.017 × 0.025 stainless steel is 930.758 (M Pa) with a standard deviation of 3.48 Mpa and the mean tensile strength in omega loop is slightly higher with 977.36 Mpa with standard deviation of 25.97. Tensile strength with 0.019 × 0.025 stainless steel in both the groups has a lower mean tensile strength compared to the 0.017 × 0.025 stainless steel. TMA 0.017 × 0.025 in both the groups has higher tensile strengths with mean of 1578.02 (SD 22.82) and 1623.58 (SD 44.8), respectively. Paired sample *t*-test between the two loop designs (omega vs. mushroom) across the two diameters has shown a statistically significant difference. The results infer that the cross-section diameter of the wire needs to be considered for the tensile strength. ANOVA for variation between the groups has shown a significant difference. *Post hoc* tuckey beta test was conducted to see the pair-wise difference in the mean tensile strength between the groups. Significant difference in the mean tensile strengths between groups using 0.017 × 0.025 inches and 0.019 × 0.025 was seen. Diameter of the wire used in the loops has a significant impact on the tensile strength. Between the mushroom loop and omega loop, a statistical significance is seen which evaluates that the loop design is an important consideration for the tensile strength. Patel *et al*. (2014) compared the forces, moments and M/F ratio, load-deflection ratio of T-loop, Keyhole loop, Teardrop loop, and Mushroom loop with finite element method, in which the forces, moments, and M/F ratios were recorded with an activation of 2 mm at each tooth node. They concluded that the highest force and moments were produced by the Keyhole loop and the lowest force was produced by the Mushroom loop.[10] Rao *et al*. (2013) evaluated the biomechanical properties of the Snail loop and compared it with the Teardrop loop and Opus loop using Ansys10 and 11 software in a computer loaded with IBM, prepared in 0.017 × 0.025" and 0.019 × 0.025" TMA wires, the result showed that snail loop prepared in TMA wire is very efficient to deliver M/F result. The present study results are similar to the finding of the Rao *et al*. (2013).[11] Rodrigues *et al*. (2010) evaluated the mechanical properties of 60 orthodontic loops of two different designs, the results were similar to the present study which showed that the metallic alloy has a significant factor affecting the sagittal force and load deflection ratio.[12]

Conclusion

According to this study, it was concluded that the alloy, cross-section diameter of the wire used for the loop, and loop design are the three important factors for considering for the space closure treatment. Orthodontic space closure must be individually assessed based on the diagnosis, desired tooth movement, and treatment plan.

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